

CHANNEL MODIFICATION

Description

Channel modification is the alteration of channel profile, planform, pattern, cross-section, bed elevation, and/or channel location of a stream segment or an entire reach. Channel modifications can be used separately or in combination to restore bank stability and reduce bank erosion (Figure 6-1). Each of these modification techniques may specifically affect the local slope, length, sinuosity, and dimensions of the channel, as well as alter basic channel processes related to sediment transport. While these techniques are not generally applied for the purpose of bank protection, channel modification techniques are very useful for treating the underlying causes of bank erosion and for preventing future problems. They should, therefore, be considered as a potential solution where there are chronic or systemic bank-erosion problems present.

The goal of channel modification is to restore or create an equilibrium (stable) condition in the stream reach (see Chapter 3, *Reach Assessment* for definition and discussion of channel equilibrium). A channel in equilibrium is one that has adjusted to the physiographic conditions (e.g., climate, geology, discharge, sediment supply) of its watershed. Keep in mind that throughout this document the terms “stable channel” and “equilibrium channel” refer to the geomorphic definitions described in Chapter 3 and do not necessarily mean a channel without erosion. A channel in equilibrium may still naturally erode as the channel migrates across the floodplain.

A channel in equilibrium can become unstable following some human or natural disturbance such as changes in hydrology or sediment loads, extreme hydrologic events, and construction of channel confinements. Bank-protection and stream-restoration plans, then, strive to attain or restore a stable channel condition, or equilibrium, based on the current and future hydrology and sediment supply of the stream.

Because all channel-modification techniques result in changes to channel process, a thorough understanding of fluvial geomorphology is an essential component of developing channel modification projects. Refer to [Appendix 6, Fluvial Geomorphology](#) for further discussion of channel planform and profile, pattern, cross-section, and channel stability and equilibrium.

Application

Channel modification techniques can be used at a site to alleviate bank-erosion problems or to facilitate mitigation. They can also be used on a reach level to address geomorphic disequilibrium, thereby reducing risks of bank erosion. Common applications for channel modification include restoring a previously straightened stream reach to its historic channel planform and profile, or restoring an unnaturally braided channel to its natural, single-channel pattern. Other objectives of channel modification include:

1. to increase habitat value and diversity,
2. to dissipate excess stream energy, and
3. to modify sediment transport capability in either the project reach or downstream.¹

For example, bank and channel stability may be achieved in a degrading channel system by modifying the channel to decrease the sediment-transport capability – the desired result being a

reduction in bank erosion while still allowing moderate channel aggradation. In a stream that is aggrading, bank and channel stability may be restored by increasing the channel's sediment-transport capability, thereby transporting downstream excess material delivered to the reach. Although channel modification can alleviate channel instability, using this technique without fully understanding its complexity (and that of the stream) could exacerbate existing problems or create new, more severe problems upstream and downstream. For this reason, it is absolutely essential that a qualified geomorphologist be involved in channel modification projects. For more information on site-based and reach-based causes of erosion and mechanisms of failure, refer to Chapters 2 and 3; and, for additional information about channel behavior and response, refer to Appendix 6, *Fluvial Geomorphology*. Refer to Chapter 5 matrices for selection criteria of channel-modification techniques relative to various mechanisms of failure.

Channel Profile and Planform Change

“Channel profile is the slope, or gradient, of the channel bed. “Channel planform” is the shape of the channel looking down on it from above (referred to as “plan view”). One common descriptor of planform is “sinuosity,” which is a measure of channel length relative to valley length. Whether a channel passes relatively straight through a valley or crisscrosses the valley several times is a function of its sinuosity. Sinuosity and profile are inseparable characteristics of a stream channel; its sinuosity is a function of its slope, and vice versa. Adjustments to either slope or sinuosity will necessarily result in changes to the other. The exception to this rule is in channels with significant grade breaks, such as small dams or other drops, where slope can be changed significantly by removing the grade break. This type of change would not directly affect the channel's sinuosity. Additionally, changes to a stream's profile or plan will result in a change in its energy and sediment-transport capacity (see Appendix 6, *Fluvial Geomorphology*).

Modification of the channel profile can occur by structurally altering channel planform or the channel slope. Channel slope can be increased by shortening the channel or decreased by lengthening the channel, depending upon the type of desired impacts to a reach. Channel shortening can best be accomplished by straightening a channel through a reach (reducing sinuosity). Channel lengthening can be accomplished by restoring a single meander or adding even more meanders to a previously straightened channel. Modification treatments can also include the installation of drop structures that change the channel profile by increasing the channel-bed elevation at a certain point. This would reduce upstream slope and increase downstream slope.

Channel-Pattern Change

The most common channel patterns that occur naturally are straight, meandering, and braided (Figure 6-1).² Several local and watershed-wide factors determine the pattern of a specific river reach, including hydrology, slope, bank structure, and sediment and large woody debris characteristics. When any one of these factors changes enough to cross a threshold value, channel-pattern change may be abruptly initiated, and usually results in a less stable channel system. In some cases, relatively small changes in climate or land use may trigger large changes in channel characteristics of natural streams.³ For further discussion of the concept of geomorphic thresholds, refer to Appendix 6, *Fluvial Geomorphology*.

Channel-pattern modification is used to force an unstable pattern into one more stable. This may entail changing the channel pattern from one form to another; for example, from braided to meandering. Channel-pattern modification is a major undertaking, involving reconstruction of the channel bed, habitat features, channel banks and floodplain. Channel-pattern modification should be considered only where the existing pattern is in disequilibrium.

Channel Cross-Section Change

Changing a channel's cross-section involves altering its bankfull width, depth, or channel shape, and can include modification of channel banks and bars. A common application of cross-section modification focuses on narrowing or widening a channel to effect a change in sediment transport by altering channel hydraulics. It can also be used to reduce shear stresses in a channel by reconstructing its floodplain. Another useful application of cross-section modification is to increase the availability and variety of fish habitat by creating asymmetrical features across the channel.

Narrowing a channel can also be beneficial in stabilizing a stream in disequilibrium, depending upon the particular circumstances at the site. This can be achieved artificially or by encouraging the channel to narrow itself by restoring vegetation and/or debris collection at the site or the addition of in-channel roughness elements.

If, on the other hand, a channel has become incised, it may become necessary to *widen* it. Widening efforts in such a situation would be used to develop a new floodplain surface that is connected to the channel at the new, incision-induced elevation.

Cross-section modification may also involve *altering a channel bank slope* to provide greater cross-sectional area. This involves excavating a bank and reshaping it from a steep or vertical face to a lower slope. Bank reshaping is a necessary component of several techniques described in these guidelines and provides a number of benefits to the stream system. Refer to the section in this chapter entitled, "Bank Reshaping" for further discussion.

The *removal of point bars* is often perceived to be a beneficial cross section adjustment; however, its effectiveness is generally limited and temporary at best. Point bars are depositional features located on the inside of meander bends. While point bars and eroding banks evolve together, one does not generally create the other. They are simultaneous products of the channel flow-pattern. The channel planform creates the bend hydraulics; as the distribution of shear stress causes scour on the outside of the bend, it creates deposits on the inside of the bend. If the desired outcome of point-bar removal is to discourage bank erosion on the opposite side of a bend, it is not likely to have any lasting effect. It is also important to differentiate between point bars and mid-channel bars, which evolve and influence stream flow differently. See [Chapter 2: Site Assessment](#) for additional information.

Although gravel bar removal seldom provides any long-term protection for the opposite bank, it may temporarily reduce shear stress by increasing the cross-sectional area and reducing velocity. In order for this process to occur, stream energy must be redirected downstream by lowering the water surface and straightening the channel. Point bars that are skimmed or removed, however, usually rebuild within the next flood season, and the cut bank may begin eroding again even

before the end of that flood season. For only a temporary benefit at the project site, the unintended consequences generated in the upstream and downstream channel may be significant. It is important, therefore, to determine whether removal of a point bar is the correct solution for the problem, as well as if the effects to the upstream and downstream reaches can be tolerated. Reaches with low bedload-transport rates and very stable downstream banks may be more tolerant of point-bar removal than others.

Cross-section change may also include the *relocation and/or removal of artificial levees* to provide overbank flood relief. The removal of artificial levees, if not planned well, can cause impacts comparable in magnitude to those of the initial levee installation. These implications must be well investigated and understood before attempting such a large-scale cross-section adjustment.

Channel-Bed-Elevation Change

The depth of a channel can be changed by raising or lowering its bed elevation. Bed elevation is linked to channel slope – if the bed elevation is changed, the channel profile must also change within the site, upstream and/or downstream. Channel-bed-elevation changes are usually implemented by installing grade control, drop structures, roughness elements, or steepened channel sections. Lowering the bed elevation is accomplished only through excavation (dredging) and has little practical application for establishing stream equilibrium or creating fish habitat.

Channel-bed-elevation change is useful in restoring a degrading (incising) channel. An increase in bed elevation can aid in reconnecting the degraded channel to its floodplain. Degraded channels that are reconnected to an active floodplain become more stable because water depths and velocities in the channel are reduced. If flood flows spread out over the floodplain during relatively frequent floods (one- to five-year return-interval events), channel erosion is minimized. Channels that are confined to ten-year or greater flood flows have sufficient energy to move large quantities of material. Massive channel erosion can occur if flood flow is confined within the channel during a 20-year or even 50-year flood event. Incised channels have a greater flow capacity so that an even greater discharge level is needed for over bank flow. The results can be catastrophic in terms of bank and channel erosion, including the increased risk of catastrophic channel change. Therefore, raising the elevation of an incising channel bed should be seriously considered as an effective means of stabilizing it.

Channel Relocation

Channel relocation changes the location of the channel while preserving or recreating other characteristics, such as overall channel profile, pattern, cross-section, and bed elevation. The purpose of channel relocation is normally to move a channel away from an eroding bank. Relocation may also be used where a significant building or road is directly threatened by erosion. Channel relocation is often a means to solve problems of channel encroachment and/or confinement, and to foster the development of a new, stable channel with healthy riparian buffers.

A channel can be entirely relocated to a new alignment, or just moved laterally within the existing alignment. One option is to deflect the flow laterally away from the hazard area using

flow-realignment techniques (e.g., groins, barbs, engineered debris jams or anchor points). Flow-realignment techniques should only be used in situations where there is no concern about impacting the channel, particularly the bank across from and downstream of the structure. Realignment techniques will change the meander shape locally and for some distance downstream, making appropriate site selection critical.

Emergency

Channel-modification treatments are not appropriate for emergency situations. Channel modification requires dewatering and careful analysis and design before implementation. However, it is possible to effect a change in channel alignment during an emergency using temporary groins. Refer to the section in this chapter entitled, “*Groins*” for further information on their use and design.

Effects

The potential effects of channel modification must be carefully assessed for a project reach. If implemented correctly, channel modification can restore natural features that fit the current and/or future conditions of the watershed. Erosion can be restored to a gradual and predictable rate, with habitat and other ecological conditions optimized. When properly applied, channel-modification techniques can result in a one-time, cost-effective fix, preferable by far to the periodic and chronic-fix alternative of treating one bank at a time..

However, without a clear understanding of the complexities of channel-modification techniques and of the stream channel in question, problems may arise. Channel modification will generally result in changes to sediment-transport characteristics of a reach. For example, a decrease in stream gradient, resulting from channel lengthening, results in lower stream energy and may cause aggradation due to sediment deposition. This will result in a higher water surface during a flood, leading to more frequent inundation of the floodplain. Therefore, careful analysis and design are required.

Design

Detailed designs are beyond the scope of this document because of the relative complexity and variability in channel-modification projects. Details of specific channel modification projects consist of many of the techniques described in this guideline. A specific guideline will be developed in the near future with additional technical details of channel design. A qualified geomorphologist should be consulted to help evaluate the necessity and applicability of major channel-modification work and to assist in design.

At a minimum, field data collection should include the following seven elements:

1. stream gradient in the project area and adjacent reaches;
2. channel cross-sections;
3. bedload and bed-material sizes;
4. streambank stratigraphy;
5. channel mapping with meander belt width, meander wavelength, radius of curvature and sinuosity;

6. habitat mapping including the influence of large-woody-debris, geology, and confinements on channel character and habitat; and
7. floodplain mapping with topography.

An analysis of historic photos and maps can provide vital information for channel-modification work. However, if existing bank erosion is a result of changed hydrology or sediment supply, then historic photos cannot provide a basis for reconstruction. Careful analysis of the watershed should accompany any channel-modification work to determine if there has been significant alteration of the watershed hydrology. If urbanization, timber harvest, grazing, agriculture or other human activities have affected the watershed, the hydrology may be significantly and permanently altered. Natural changes such as fire should also be considered. Selection and design of channel-modification treatments should be based on historic photos only where changing watershed conditions can be accounted for, or where the watershed has already been restored to historic conditions. In any case, future anticipated conditions are a critical element of any channel modification design.

Reaches vulnerable to spontaneous channel-pattern change should be identified within flood-hazard management plans and watershed plans. Such reaches might be considered as possible off-site mitigation opportunities for other activities.

Reference Reach

The recommended design approach for channel-modification projects addressing site-specific erosion problems is based on the reference-reach concept. A reference reach is a stable reach located either upstream or downstream of a project, or in a nearby watershed with similar hydrology, precipitation, soils, geology, relief, vegetation and land use. Applications for reference-reach design include channel modification to enhance or restore habitat and/or to address site-specific erosion problems.

This approach assumes the reference reach is in a stable and unchanging watershed condition. If necessary, streams of differing size or drainage area can be used as reference reaches, as long as dimensionless parameters, such as width-to-depth ratio, are used. Several reference reaches might be used for added confidence. If a reference reach is not available, then regional hydraulic geometry relationships can be used to estimate channel dimensions, though this is not the preferred method.

Reference reaches may be used to generate a range of acceptable values for channel parameters such as pattern, plan, and profile. However, whenever a reference-reach design approach is used, *channel slope in both the reference reach and the design reach must be the same*. Pattern, profile, and dimensions of the project site are then compared to the reference reach. If the project reach varies significantly from the reference reach, it may be an indicator that channel modification is appropriate. The significance of variation can be roughly evaluated by comparison to the variance within relationships in regional hydraulic geometry data. Geometry and pattern of the constructed channel are then derived by correlation to the reference reach.

Habitat

Regardless of the design method used, there must be a habitat-preservation or -restoration component included in the project. Habitat is directly associated with channel design in that most habitat features are inextricably linked to channel evolution and stability. Stable channels ideally provide sufficient habitat for resident and migratory fish. However, because many components of a stable and natural system may be absent, such as large, woody debris, it will be necessary to install habitat features as part of the modification. Refer to Chapter 4, *Considerations for a Solution* in determining mitigation targets as a reference for quantifying habitat needs. Habitat must be designed as a self-perpetuating function rather than just as a feature. The hydraulics of the channel must support and maintain the habitat features intended, such that woody debris is recruited and retained, scour develops to form pools and gravels are sorted to form areas for spawning.

Debris

Debris and vegetation each perform significant roles in the evolution of channels; these roles must be accommodated in the design of new channels. Those roles are so significant that there are few, if any, true alluvial channels in Western Washington. Consequently, large, woody debris must be incorporated into channel-modification treatments on Western Washington projects. East of the Cascade Mountain divide, however, large, woody debris should be used only where it naturally occurs, or where habitat limitations warrant its inclusion.

Riparian Planting

If riparian vegetation is damaged or limited in coverage, an extensive riparian planting component should be included in the project. Protection of the riparian corridor from livestock may be required to ensure success of the riparian plantings and long-term success of the project. Stockpiling fertile topsoil is critical for areas that will be highly disturbed. After the excavation and fill is complete, the topsoil can be replaced to provide an adequate base for riparian plantings. Refer to [the section in this chapter entitled, “Woody Plantings, Herbaceous Cover and Buffer Management”](#) and [Appendix 8, Planting Considerations and Erosion-Control Fabrics](#) for further information on riparian planting.

Biological Considerations

Restoring a stream to a more stable, natural shape can have tremendous benefits for fish and wildlife. If the floodplain is reactivated, the riparian community will be better able to reestablish and provide food and shelter for wildlife. Floodplain reactivation and the related increase in groundwater and surface-water interaction during summer and winter periods may also moderate water temperature extremes – a benefit to fish. Channel narrowing in combination with riparian-vegetation establishment might also moderate water-temperature extremes.

Channel modification can cause extensive short-term disturbance to macroinvertebrates, amphibians, fish and some nesting birds due to in-stream disturbance, fine-sediment deposition, channel abandonment and loss of riparian vegetation. Although a stream with restored profile, pattern, or cross-section will provide better habitat in the long run, the necessary excavation, fill material, and vegetative disturbance may cause substantial damage to existing habitat. If a stream channel is being completely moved or turned back into an historic meandering channel, much of the existing habitat can be lost for at least several years depending upon the stream system and ecoregion.

Fish trapping and relocation may be required to remove fish from the project construction area. The lower end of an existing channel might be left open and connected so there is in-stream habitat until the new channel is established with vegetation. A new channel may be left exposed for a winter so it can weather before flow is diverted into it.

Mitigation Requirements for the Technique

Mitigation may not be required for channel-modification treatments if there is a net habitat benefit by the project. Mitigation may be required for one type of habitat that is replaced with another or for the time delay for the habitat to be functional as described in Chapter 4. Impacts described in the previous section and associated with construction activities, site access, and flow diversion may require mitigation.

Mitigation Benefits Provided by the Technique

Channel modification may provide substantial mitigation opportunities for spawning habitat, channel and habitat complexity and diversity, flood refuge, and for lost opportunities associated with bank-protection projects elsewhere. Channel modification can greatly reduce the impact of bank-protection activities within a specific reach when compared to the alternative of cumulative impact due to chronic, individual, bank-protection projects throughout the reach.

Risk

Habitat

Channel-modification projects should be designed to provide habitat benefit. However, large-scale channel modification may result in temporary impacts to, and loss of, habitat due to disturbance. Months to years may be required for full recovery of some habitat components. There is a risk that a poorly designed channel-modification project may have a negative effect on habitat rather than a positive one. There is a trade-off between risk and habitat preservation and restoration as well. A channel must have a certain amount of deformability in order to sustain and generate quality habitat for fish. Additionally, a newly constructed channel that is not well protected by vegetative structure carries the risk that high-flow events could impact it and the downstream reach more severely than intended by the design.

Infrastructure

Channel modification may result in risk to infrastructure if inappropriately designed due to the complexity of accurately predicting relationships among various channel attributes in design and implementation. However, their intent is to reduce channel instability and, thereby, reduce risk to infrastructure.

Reliability/Uncertainty in Technique

Because all channel-modification techniques result in changes to channel process, there is a risk that an inappropriate design or unanticipated conditions will cause a project to fail. A thorough understanding of fluvial geomorphology is an essential component of developing channel modification projects. Refer to [Appendix 6, Fluvial Geomorphology](#) for further discussion of channel planform and profile, pattern, cross-section, and channel stability and equilibrium.

Materials Required

Construction of channel-modification projects will generally require dewatering of the channel either by diverting all flow or by isolating parts of the channel during construction. Dewatering is essential to facilitate construction and to control sediment inputs to the stream. Channel-modification projects are constructed using native materials available on site, through stockpiling, redistribution and rearrangement of existing channel materials. If not already present in the channel, large, woody debris may have to be supplied from elsewhere. Many channel-modification projects require reconstruction of channel banks. Refer to specific bank-protection techniques in this chapter for descriptions of materials required for their construction.

Construction of channel-modification projects requires careful sequencing of work phases. Construction steps may include (not necessarily in this order): constructing a diversion channel; diverting stream flow; rescuing fishes from areas to be dewatered; dewatering, gaining access to and stockpiling imported materials, waste materials and transitional redistributed materials; constructing damaged or new banks; installing erosion and sediment control; constructing and installing habitat features; and redirecting flow into the modified channel. Further discussion of these components can be found in [Appendix 13, Construction Considerations](#).

Timing Considerations

Channel modification often requires complete dewatering. Consequently, the work should be timed to occur during low-water periods. Critical periods in salmonid life cycles, such as spawning or migration, should also be avoided. In-stream work windows vary among fish species and streams. Contact The Washington Department of Fish and Wildlife's Area Habitat Biologist for information on work windows. Further discussion of construction timing and dewatering can also be found in [Appendix 13, Construction Considerations](#).

Cost

Channel-modification project costs are site and design specific and vary according to the size of the channel. Reconstruction and relocation projects may range from \$50 to \$300 per foot of channel (including reconstructed banks and dewatering), depending on the size of the channel and complexity of modification techniques. Key cost items will include dewatering systems, imported materials, and bank reconstruction. Dewatering will be a significant cost for channel modification because it requires, in most cases, complete dewatering of the entire channel or at least half of the channel. The need to import materials for any component of the modification will greatly increase implementation costs. Since many channel-modification projects require reconstruction of channel banks costs associated with acquiring bank-reconstruction materials will also need to be taken into account. Refer to individual bank protection techniques described in this chapter and to [Appendix 12, Cost of Techniques](#) for further discussion of bank construction costs.

Operations and Maintenance

Bank reconstruction and habitat elements associated with channel-modification projects require periodic inspection and maintenance or repair. They may be especially vulnerable to damage

during the first years of operation, particularly if they are subjected to high flows before vegetative components are able to provide support. While the intent of channel modification is to create a stable channel, the design must allow some deformity to occur in order to create and sustain adequate fish habitat. For this reason, moderate erosion along banks should be expected and encouraged, and some degree of maintenance and repair should be anticipated especially during the first three years of the new project. Refer to individual bank-protection techniques described in this chapter for additional information about deformity, maintenance and repair considerations.

Monitoring

Because channel-modification projects generally involve impacts to the channel and banks, they will require comprehensive monitoring of both channel and bank features, with particular attention to habitat monitoring. For a comprehensive review of habitat-monitoring protocols, refer to the Washington Department of Fish & Wildlife's work in progress, "Monitoring Salmon Habitat in Washington State - A Synthesis and Directory of Forty Protocols."

Monitoring of channel-modification projects should be initiated prior to construction, with baseline-conditions surveys of the physical channel, its banks, and its habitat value. This will allow comparison of modified conditions to pre-project conditions. Additionally, monitoring should include detailed as-built surveying and photo documentation of the project area and upstream and downstream reaches to allow for evaluation of performance relative to design.

Refer to [Appendix 10, *Monitoring and Mitigation*](#) for further discussion of monitoring considerations and practices.

References

¹Rinaldi, M. and P.A. Johnson. 1997. Stream Meander Restoration. *Journal of the American Water Resources Association* 33(4):855-866.

²Leopold, L.B. and M.G. Wolman. 1957. River Channel Patterns- Braided, Meandering and Straight. United States Geological Survey, Professional Paper 282B.

³Schueler, T. 1994. The Importance of Imperviousness. *Watershed Protection Techniques*, Vol. 1, No. 3, Fall 1994.